

# **STAR Physics at RNC**

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## **(1) Introduction**

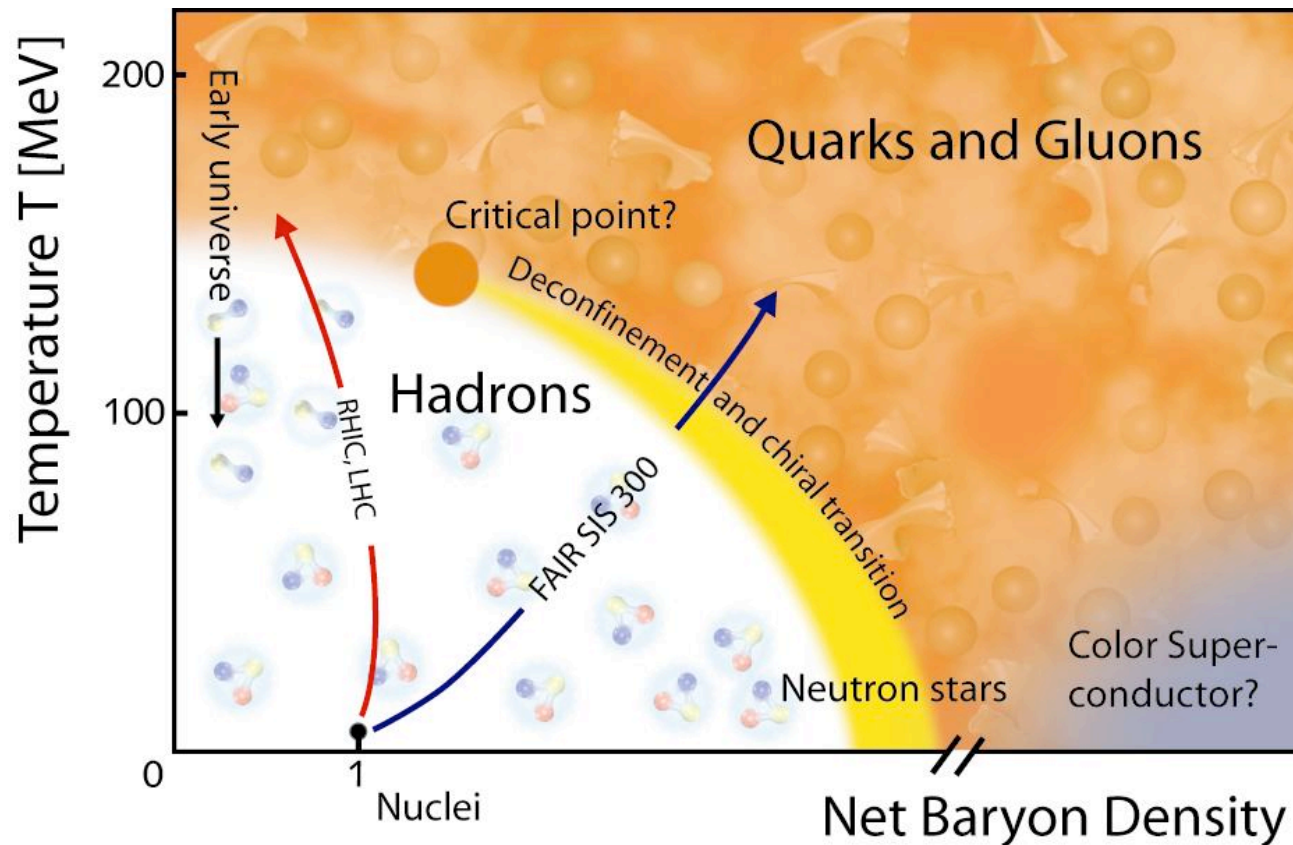
## **(2) Selected recent results**

- partonic collectivity, coalescence, di-jets

## **(3) Plan for FY09 - 11**

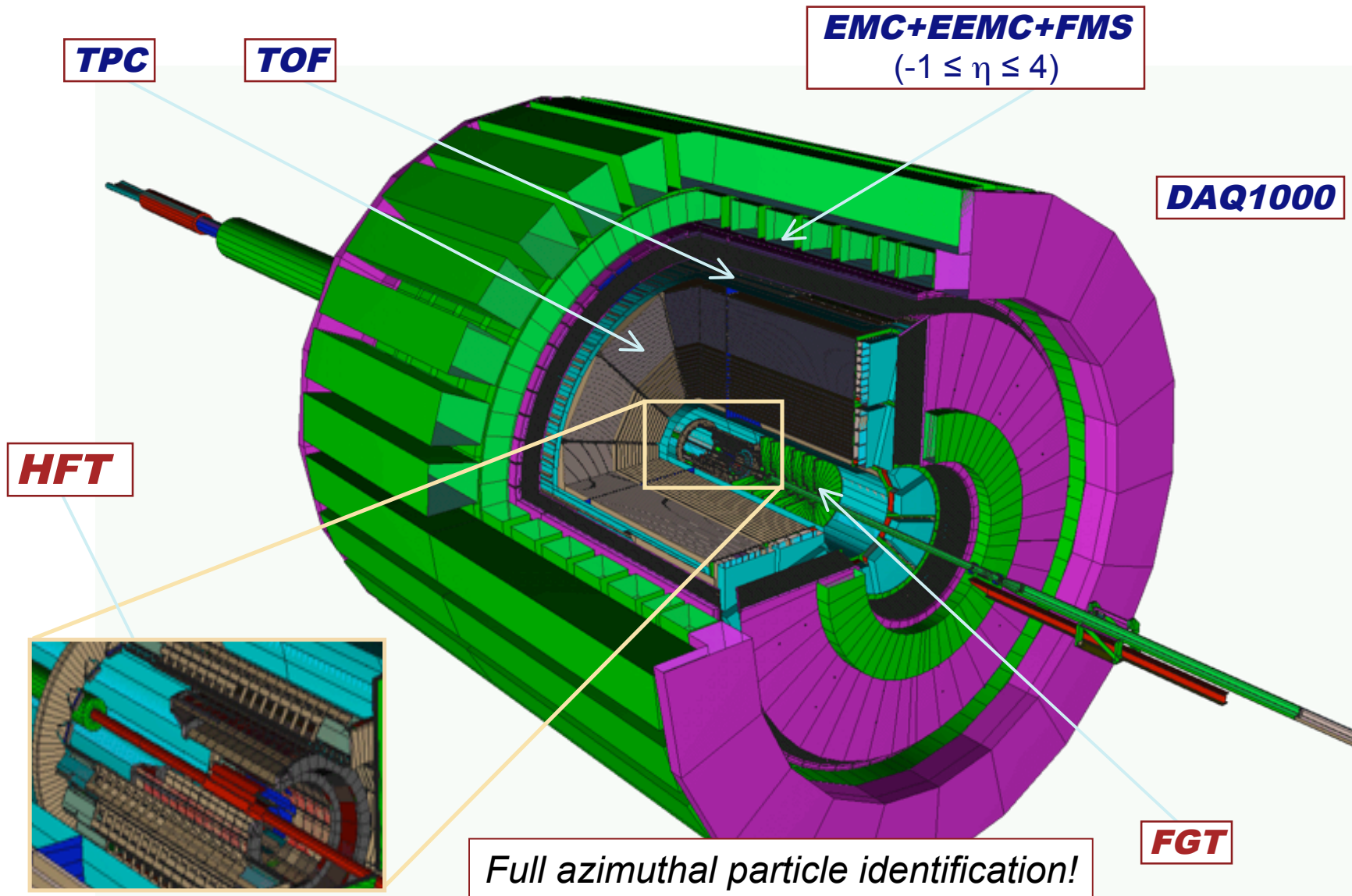
- collective velocity, full jet reconstruction, direct radiation

# STAR Heavy Ion Physics



- 1) RHIC heavy-ion program
  - Study **medium properties** and pQCD in hot and dense medium
- 2) RHIC energy scan
  - Search for **QCD critical point**

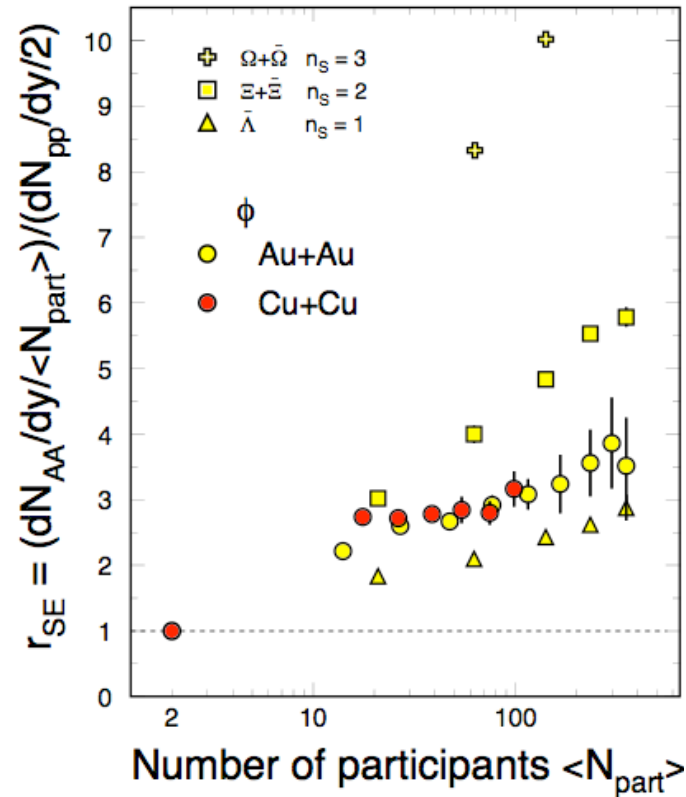
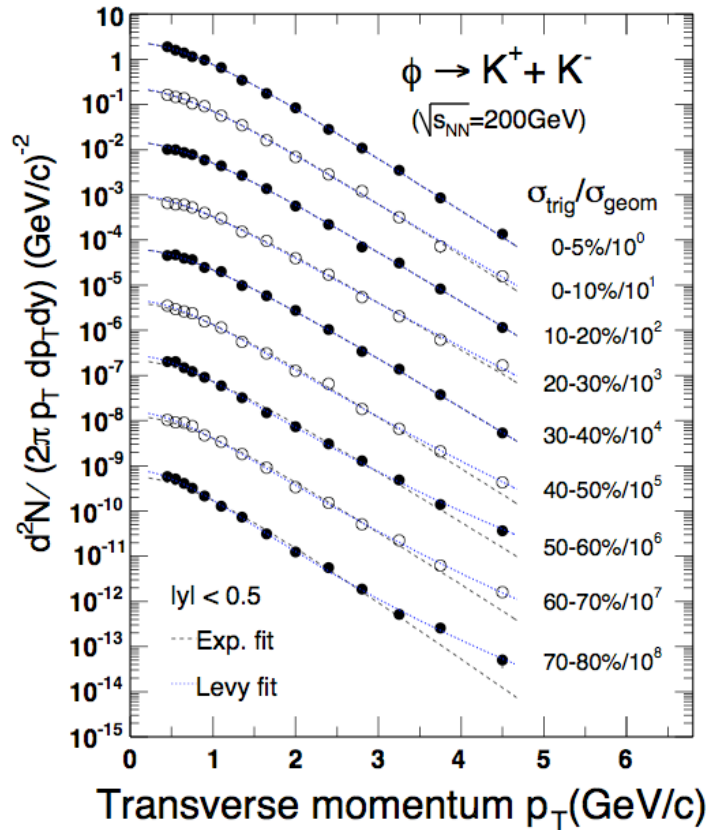
# STAR Detectors





# $\phi$ -mesons from Au+Au Collisions

STAR: PRL. **98** (2007) 062301; nucl-ex/0703033



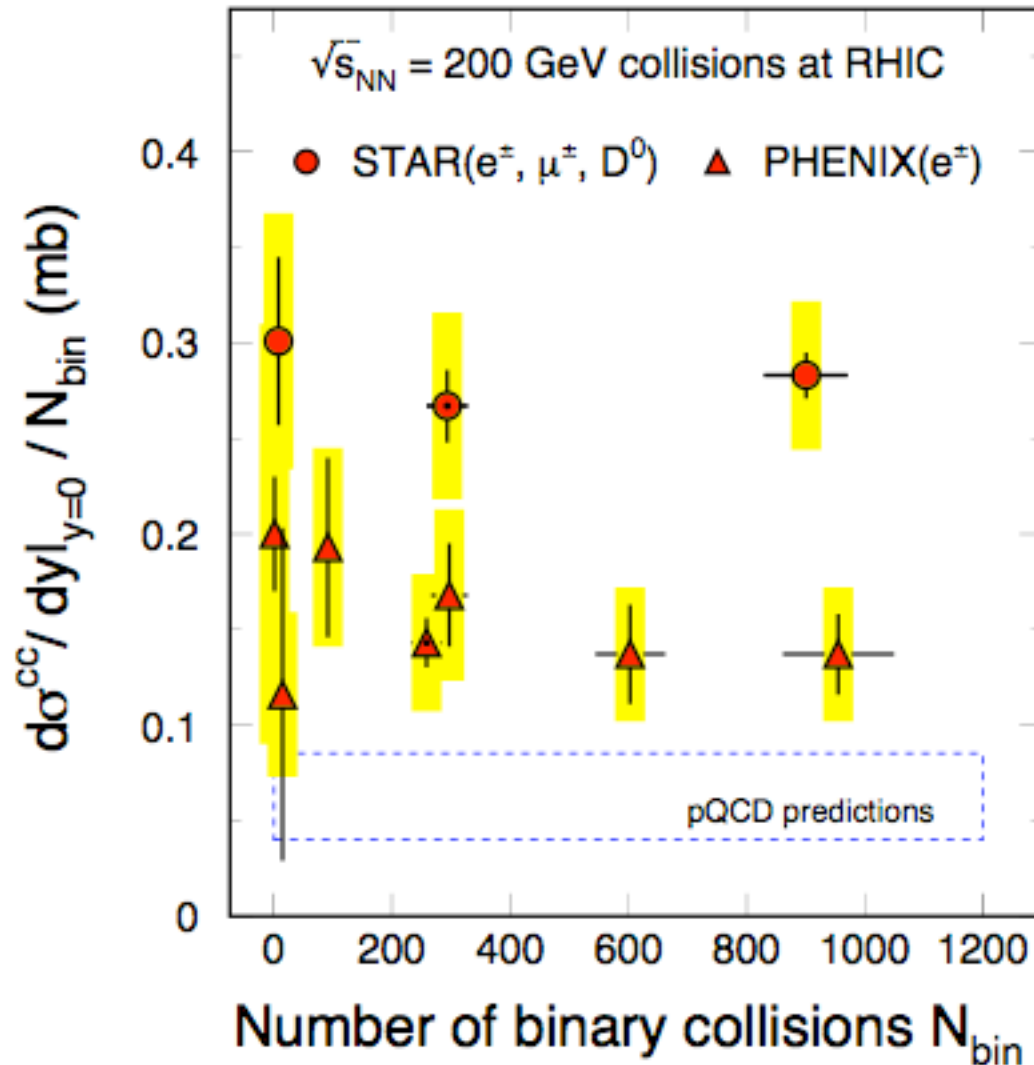
**ssbar fusion  $\Rightarrow$   $\phi$ -meson formation!**

STAR: Phys. Lett. **B612**, 81(2005)

**The observed strangeness enhancement is NOT due to the Canonical suppression!**

STAR: Preliminary

# Charm Cross-section



## $d\sigma(cc)/dy$ at RHIC

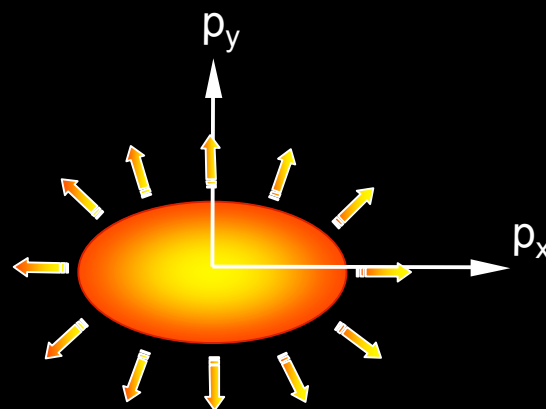
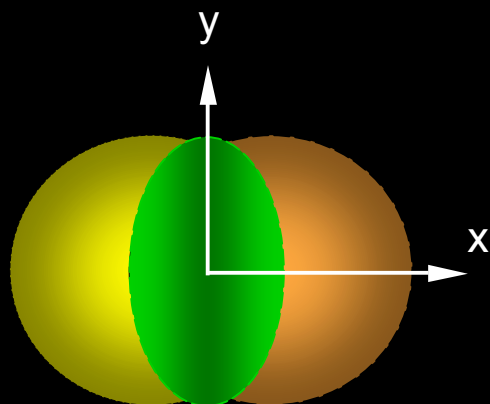
- 1) Within error bars,  $N_{bin}^{-1}$  scaling is observed!
- 2) Large systematic uncertainties
- 3) Theory under predict
- 4)  $d\sigma(cc)/dy$  at RHIC:  
  
STAR  $\sim 2 \times$  PHENIX
- 5) **HFT upgrade important**

# Anisotropy Parameter $v_2$

coordinate-space-anisotropy



momentum-space-anisotropy

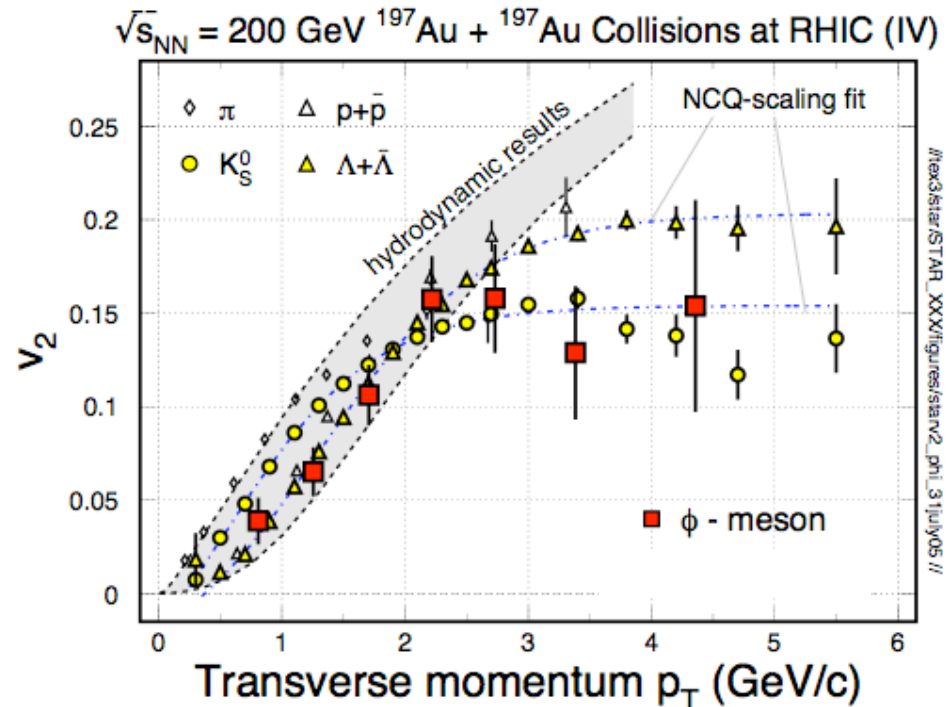
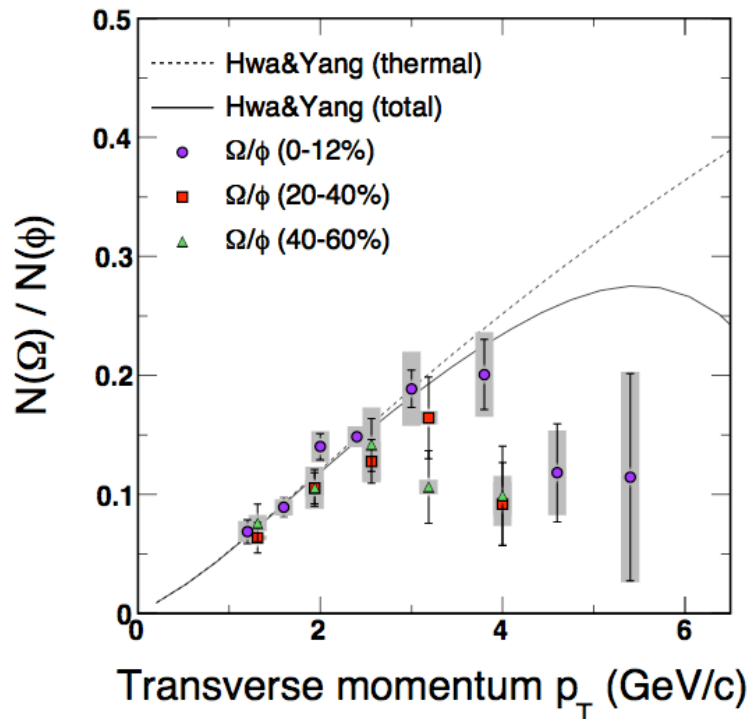


$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

$$v_2 = \langle \cos 2\varphi \rangle, \quad \varphi = \tan^{-1}\left(\frac{p_y}{p_x}\right)$$

**Initial/final conditions, EoS, degrees of freedom**

# $\phi$ -meson Flow: Partonic Flow

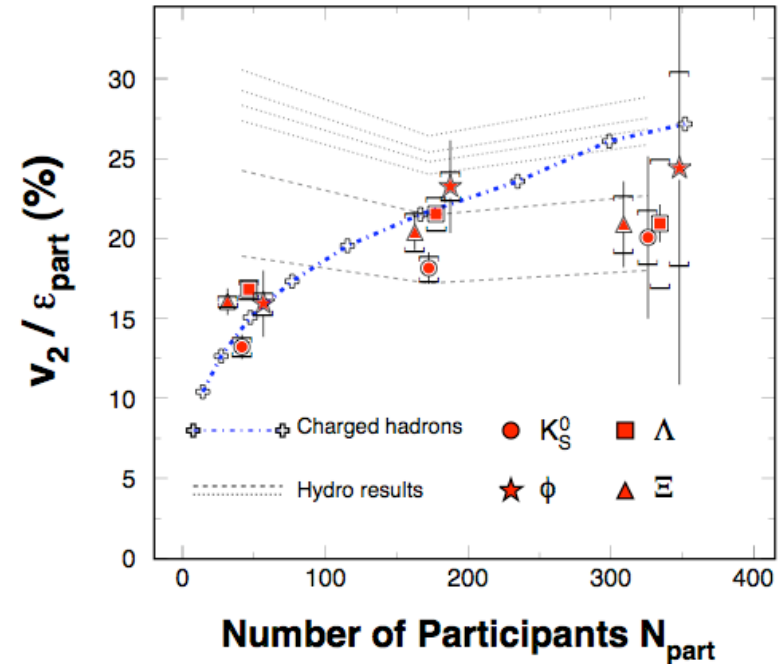
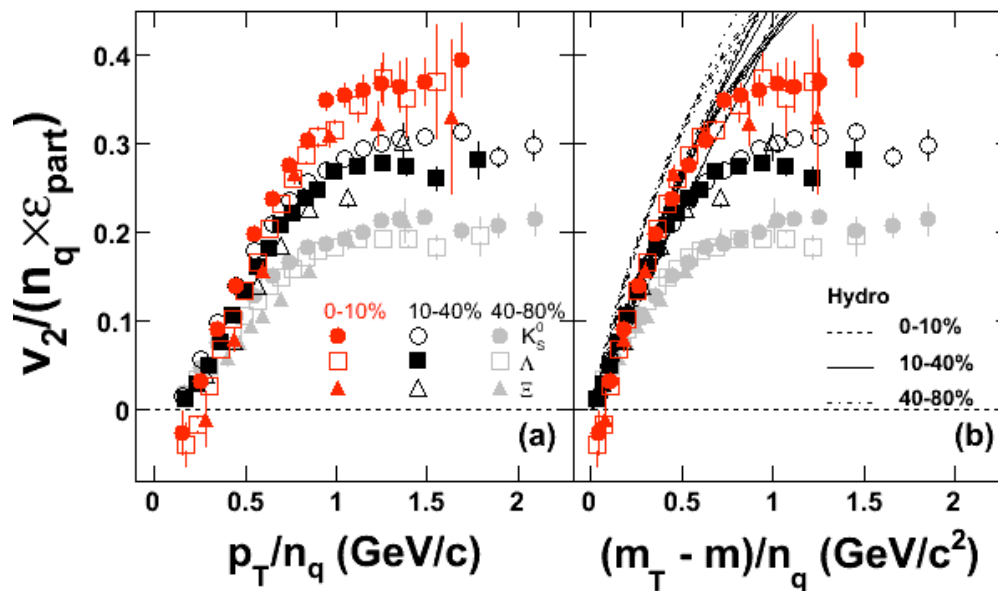


“ $\phi$ -mesons are produced via coalescence of seemingly thermalized quarks in central Au+Au collisions. This observation implies *hot and dense matter with partonic collectivity* has been formed at RHIC”

STAR: Phys. Rev. Lett. **99** (2007) 112301// \* STAR, Duke, TAMU,

# Eccentricity Scaling (?)

STAR: PRC, in print, arXiv:0801.3466v1

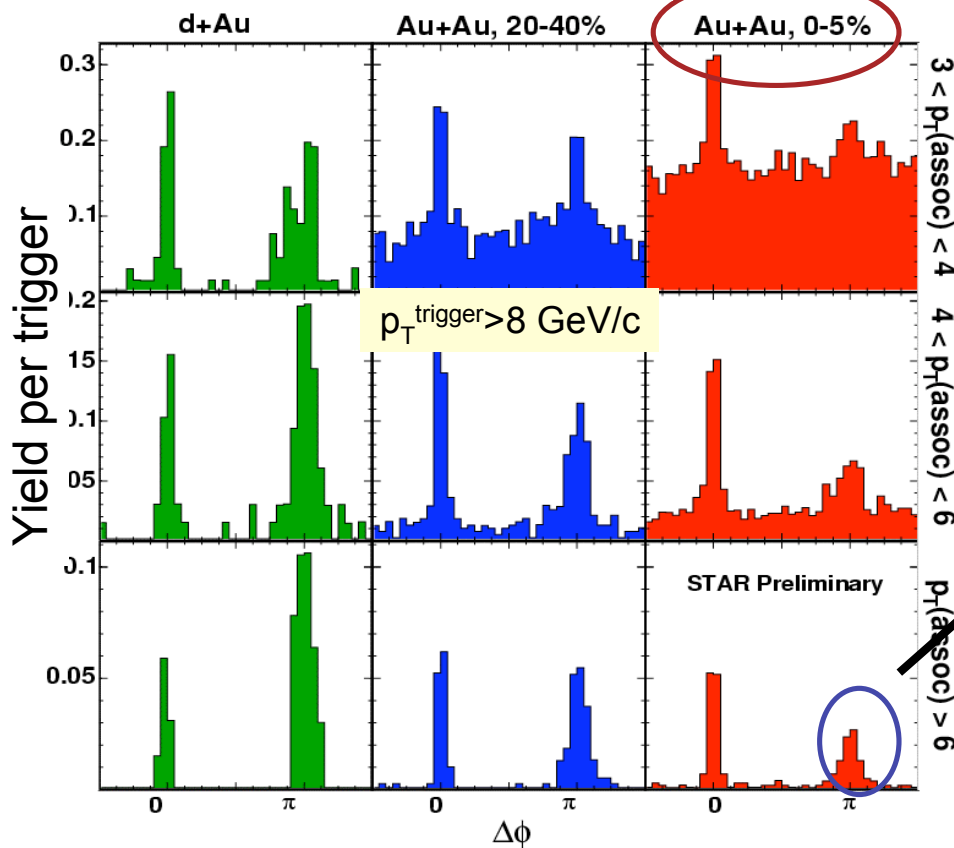


S. Voloshin, A. Poskanzer, PL **B474**, 27(00).  
D. Teaney, et. al., nucl-th/0110037

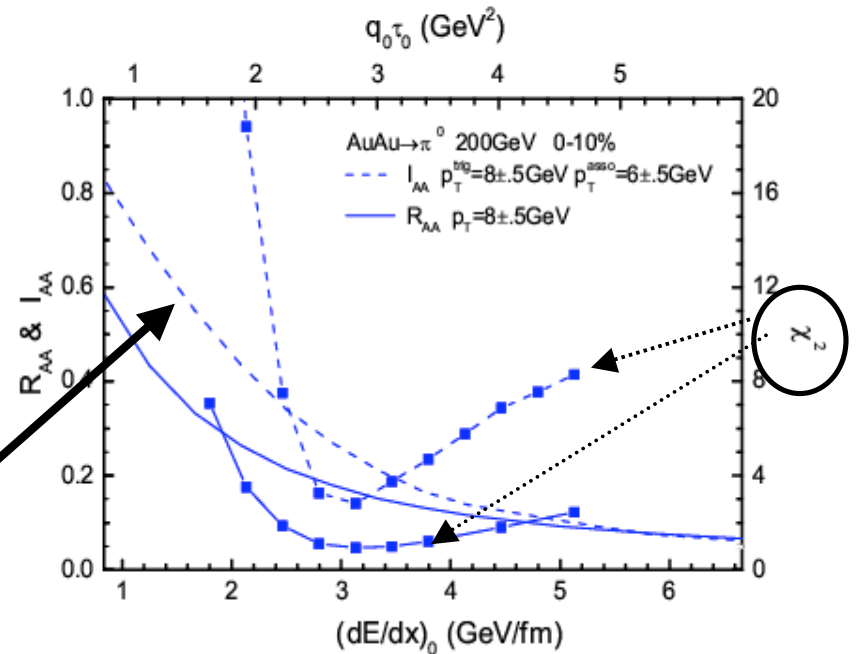
- Larger  $v_2/\epsilon_{\text{part}}$  indicates stronger flow in more central collisions.
- Clearly, no  $\epsilon_{\text{part}}$  scaling.
- **The observed  $n_q$ -scaling does not necessarily mean thermalization.**

# Di-hadron Correlations at High $p_T$

STAR, PRL **97**, 162301 (2006)

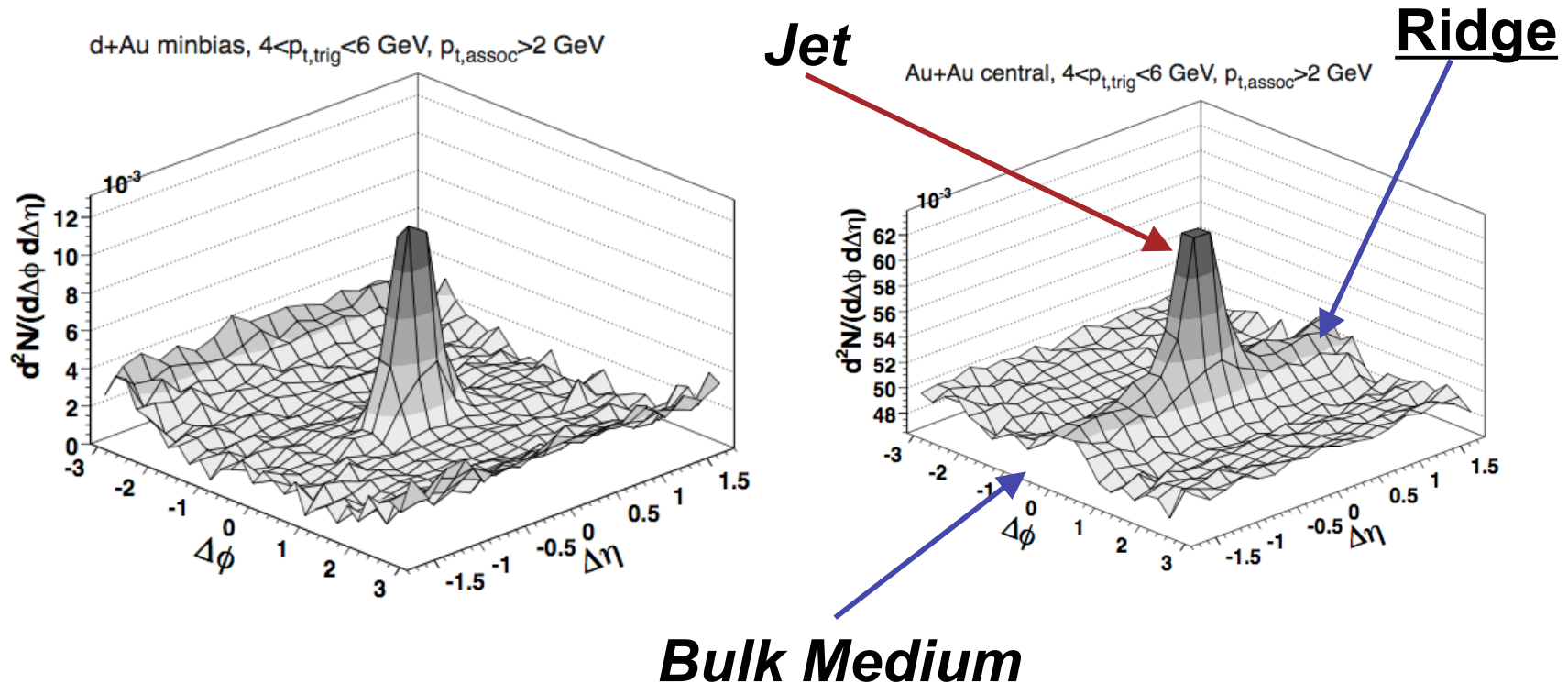


Zhang, Owens, Wang and Wang  
PRL **98**, 212301 (2007)



Di-hadron correlations results allow quantitative measure for jet quenching  $\Rightarrow$  **Parameter for energy loss.**

# The Ridge: Medium Response



Rich underlying physics: jet, bulk, jet-medium interaction, medium responses,...

*N. Armesto et al.; R. Hwa; A. Majumder, et al.; E. Suryak; S. Voloshin; C.Y. Wong*



# Results Summary

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Study **medium properties** via (i) penetrating probes, jets and heavy flavor; (ii) bulk measurement, collective flow and yields; (iii) multi-particle correlations.

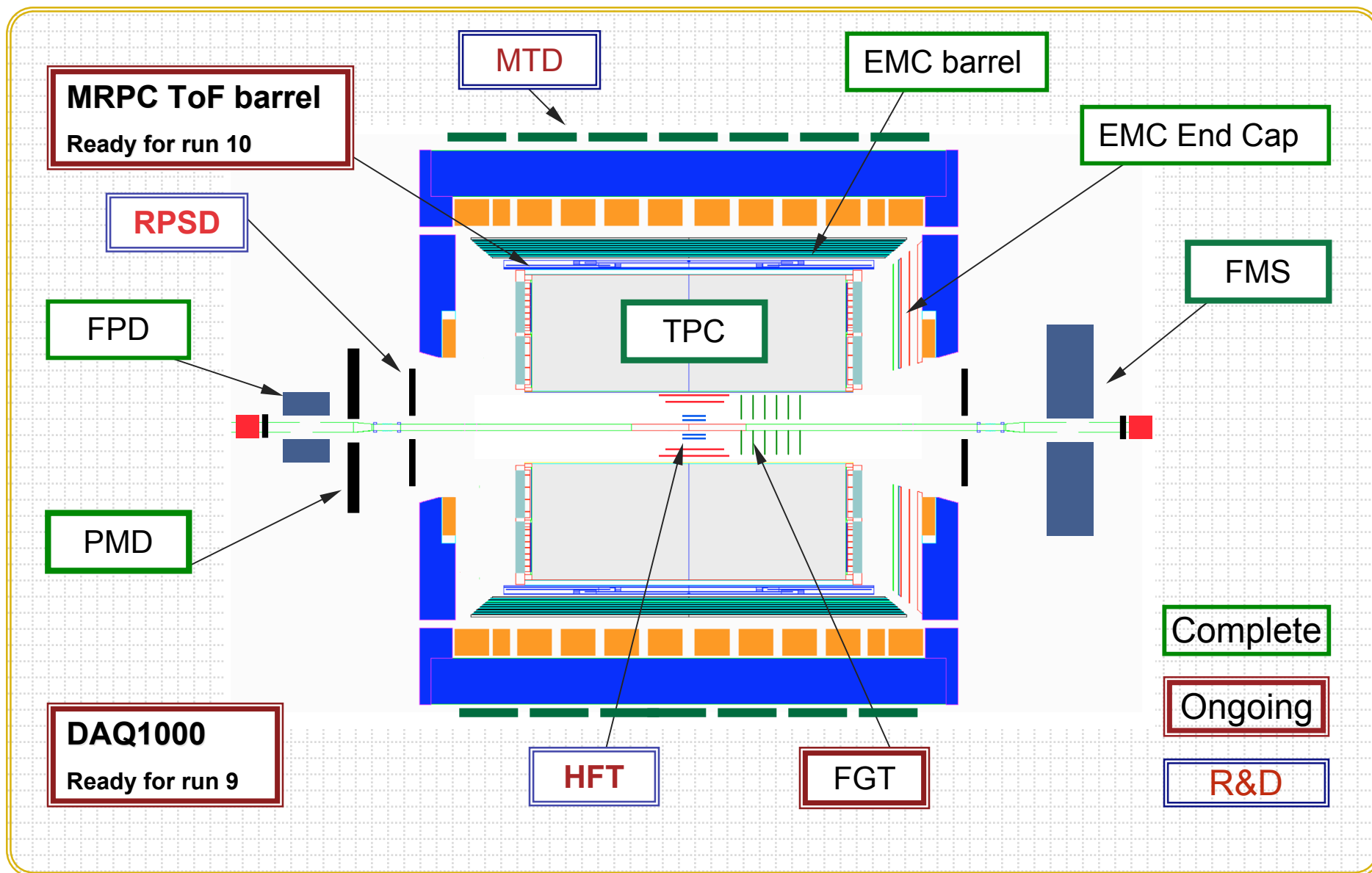
⇒ Strong collective flow with partonic degrees of freedom

- detailed studies underway to extract collective velocity parameters
- future HFT will help to address issues of thermalization at RHIC

⇒ Jet and medium correlations

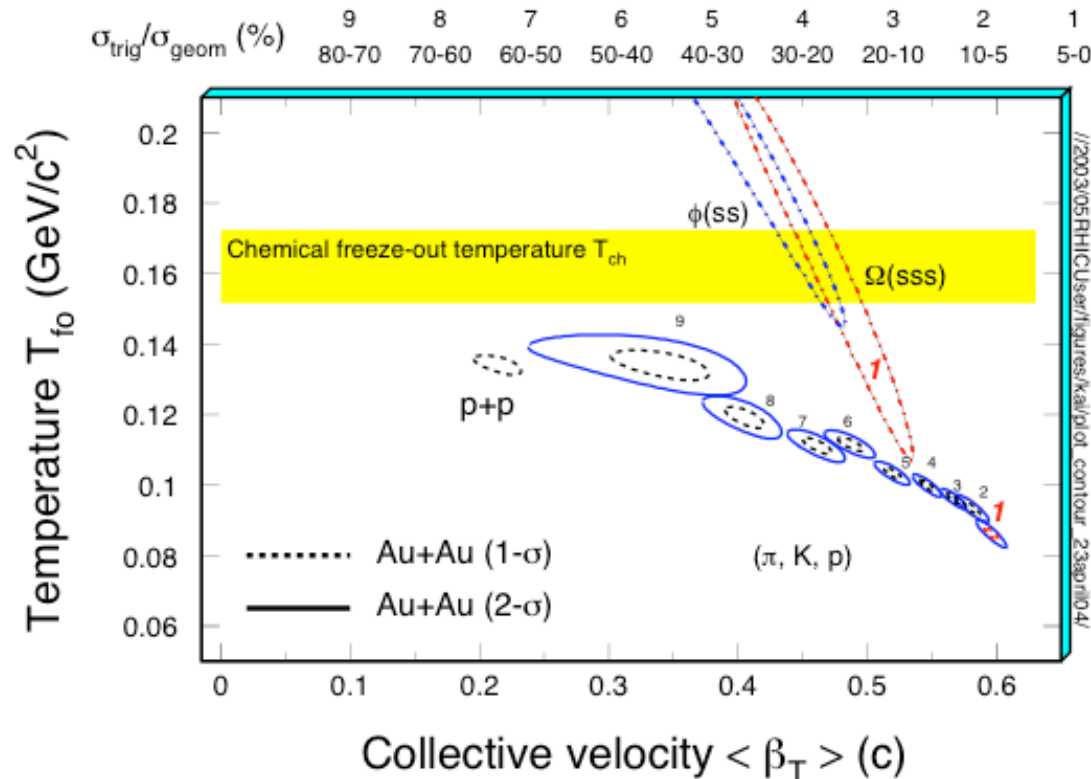
- detailed study of three-particle correlations: search for shock wave, determine parameters of the EoS
- Jet analysis can yield info on the medium, such as  $q^{\text{hat}}$ ,  $dE/dx$

# STAR Detector



# Blast Wave Fits: $T_{fo}$ vs. $\langle\beta_T\rangle$

## 200GeV Au + Au collisions



**Multi-strange hadrons freeze-out with higher  $T_{fo}$  ( $\sim T_{ch}$ ) and smaller  $\langle\beta_T\rangle$**

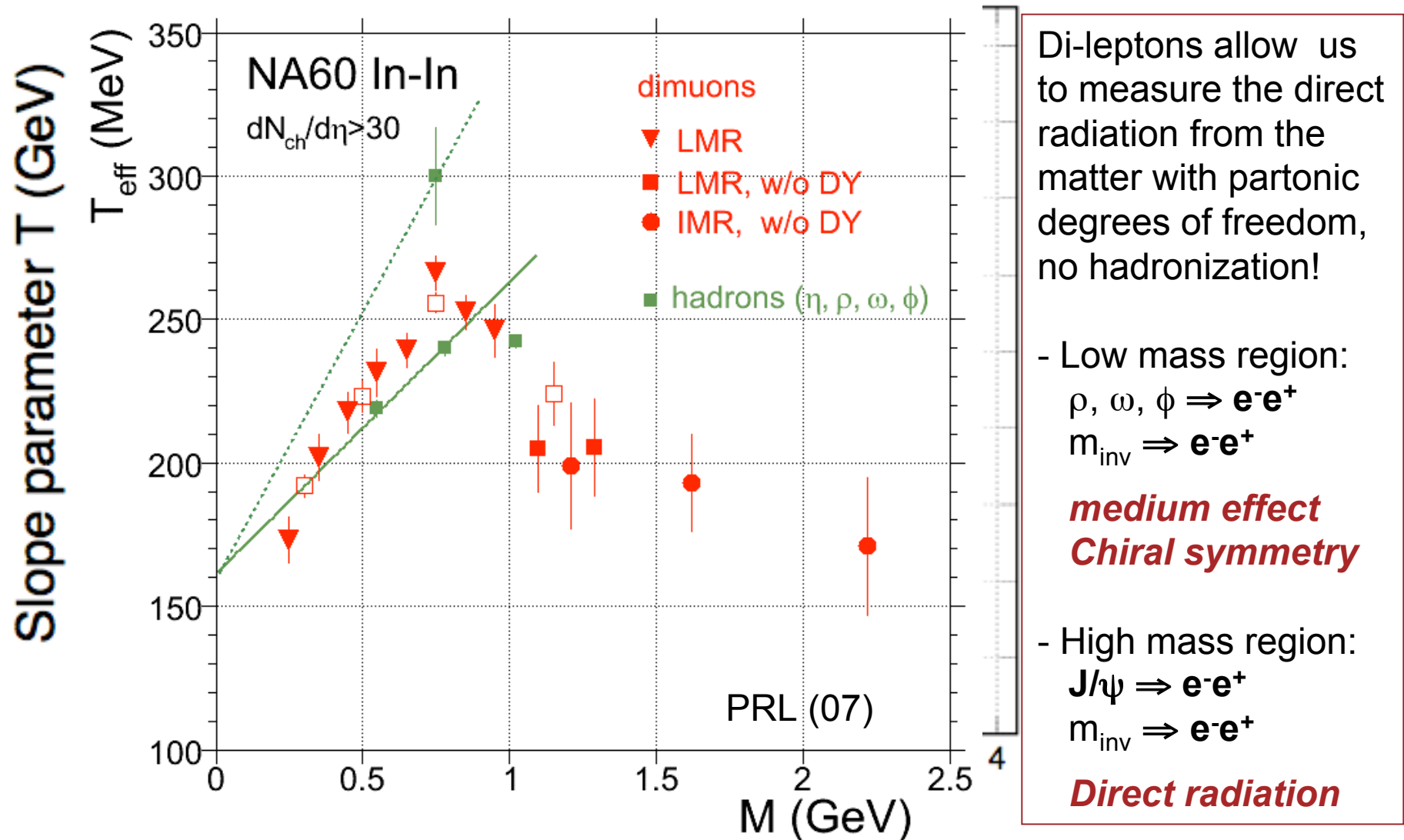
1)  $\pi$ ,  $K$ , and  $p$  change smoothly from peripheral to central collisions.

2) At the most central collisions,  $\langle\beta_T\rangle$  reaches 0.6c.

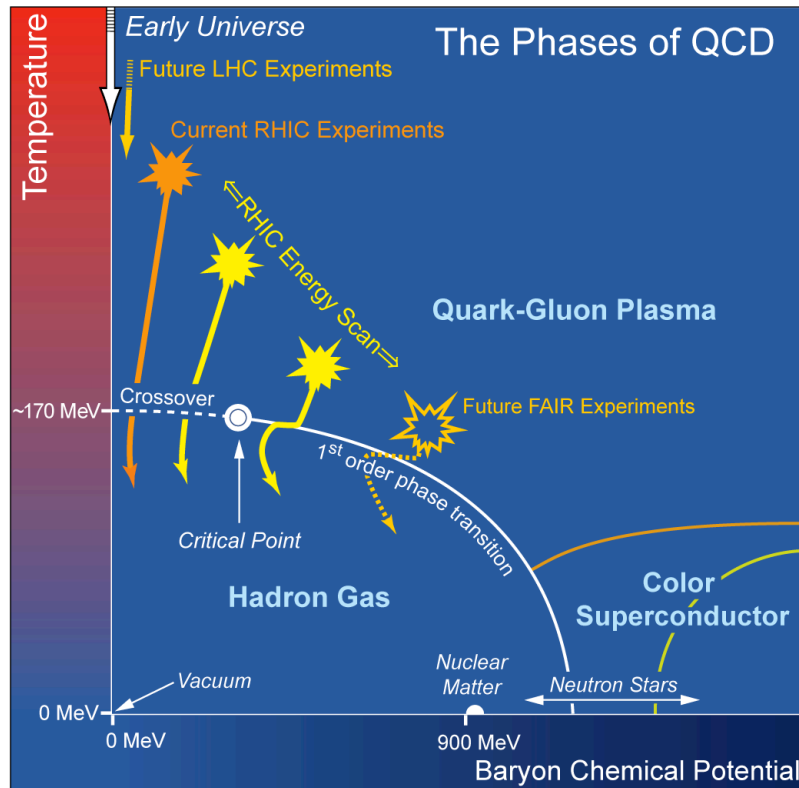
3) Multi-strange particles  $\phi$ ,  $\Omega$  are found at higher  $T$  and lower  $\langle\beta_T\rangle$

**⇒ Future: Map the velocity parameter with multi-strange hadrons. Key for partonic EOS!**

# Direct Radiation



# Search for QCD Critical Point



## STAR Beam User Request FY10

$\sqrt{s_{NN}}$ [GeV]	$\mu_B$ [MeV]	Rate [Hz]	Goal [Events]	Duration [Days]
5.0	550	0.5		7
6.1	491	1.4	1 M	20
7.7	410	2.7	2 M	20
8.6	385	4	2 M	15
12.3	300	10	5 M	15
17.3	229	25	10 M	12
27	151	30	10 M	7
39	112	50	10 M	6

## Key measurements:

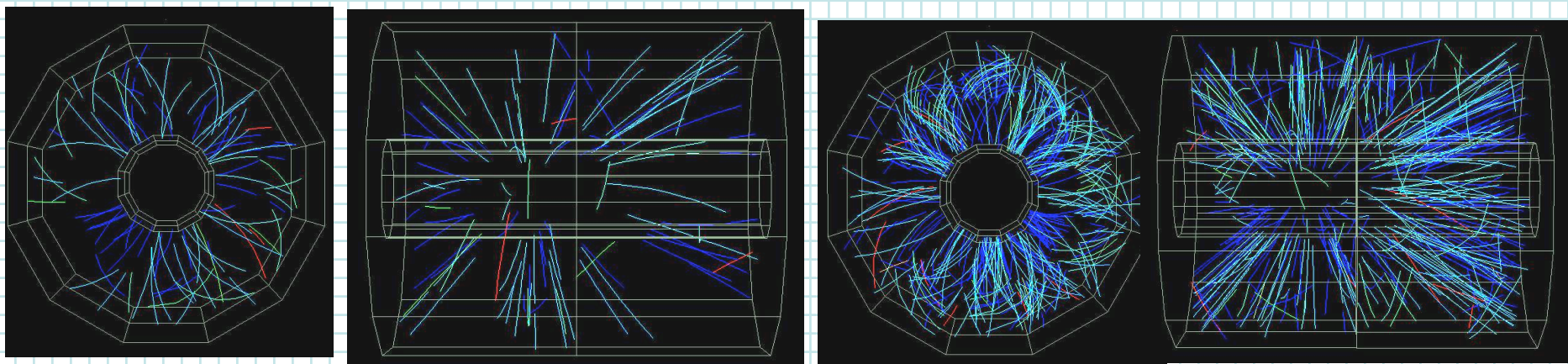
- (1) All PID hadron spectra and  $v_2$
- (2)  $K/\pi$ ,  $\langle p_T \rangle$  ... fluctuations

## Strategy:

- From high to low energy: sign for disappearance of high density phenomena
- Cover SPS range ( $\sqrt{s_{NN}} = 5 - 20$  GeV): sign for the onset of de-confinement

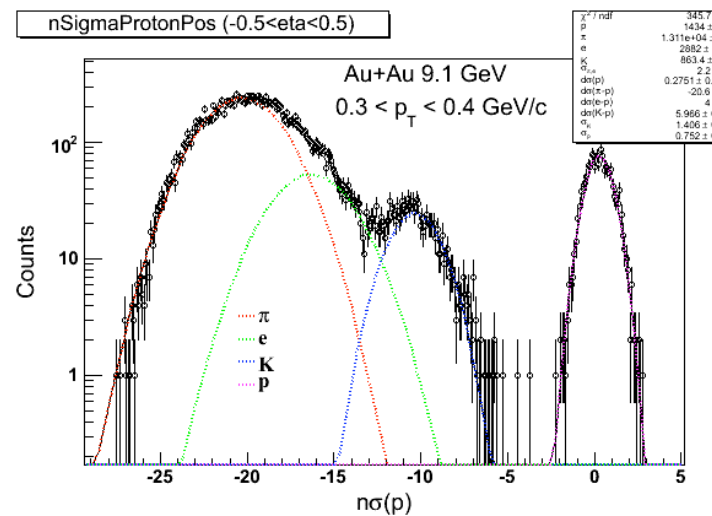
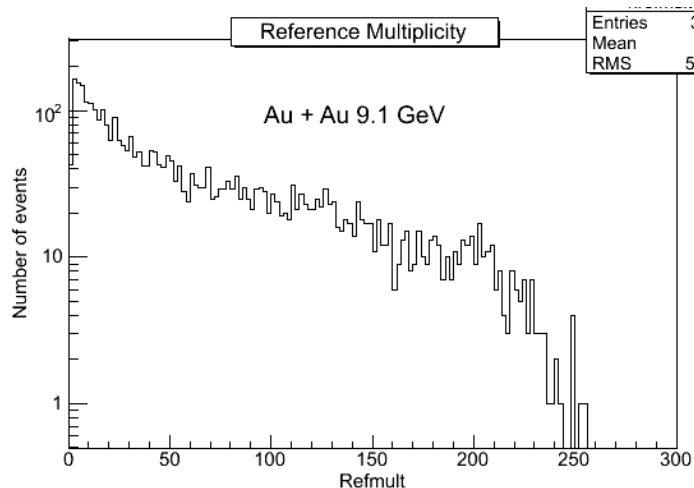
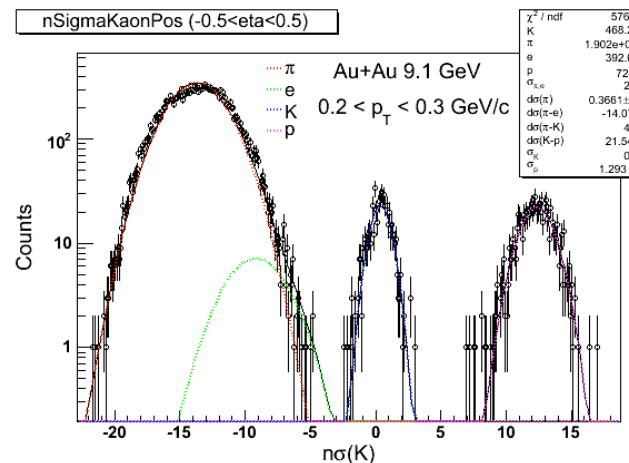
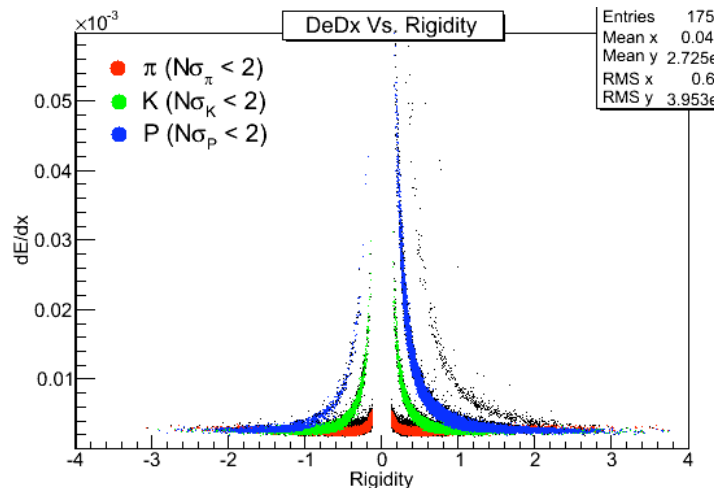
# Low Energy Test Run (9 GeV)

## *Au + Au Collisions!*



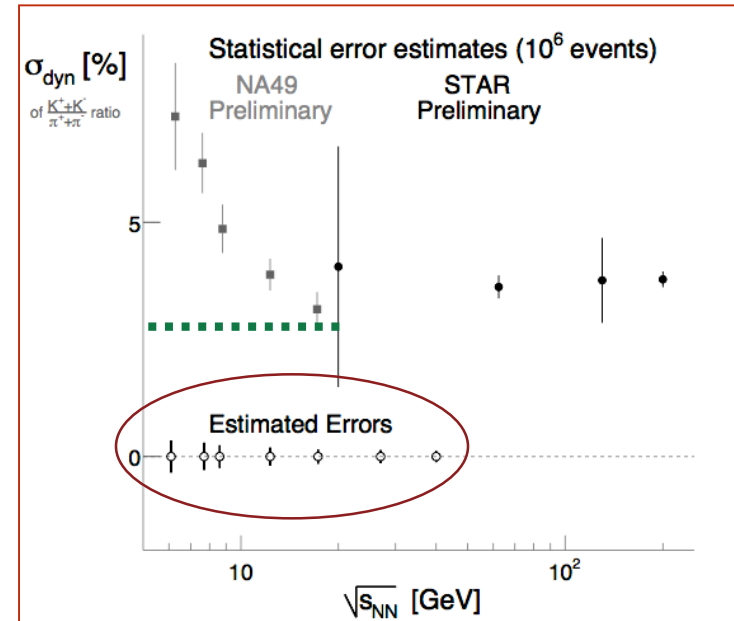
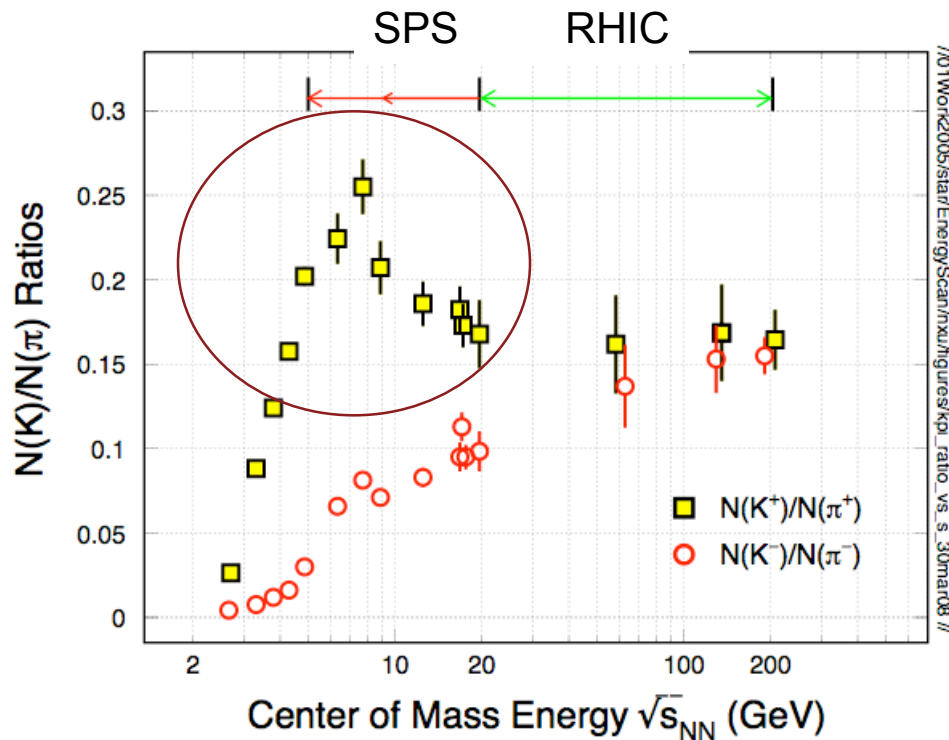
- 1) ~ 3500 collisions collected
- 2) Gain understanding of triggering issues
- 3) Determine Luminosity: rate ~ 0.6 Hz at 9 GeV
- 4) STAR studying the following:  
Particle identification in TPC; total charged multiplicity  
 $\pi$ - $\pi$  interferometry, particle ratios;  $v_1$  and  $v_2$
- 5) Physics ready with 2 - 4 Hz collisions

# Ready for Physics at Energy Scan



PID will be significantly extended using TOF

# Observables and Advantages



..... Torrieri

## Advantages at STAR:

- Large acceptance: full azimuthal coverage and  $|y| < 1.0$
- Clean particle identification: (TPC, ToF, EMC)
- Acceptance does **not** change with beam energy, systematic errors under control
- High potential for discovery

# Future Plan

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- (1) Using strange and multi-strange hadron spectra and  $v_2$ , map out parameters of collective velocity with partonic dof  
***⇒ To understand the QGP formation in top energy collisions at RHIC.***
- (2) Full jet reconstruction at RHIC ***⇒ Extract energy loss parameters***
- (3) Utilize full azimuthal coverage of TOF, measure di-electron mass spectrum up to  $J/\psi$  mass ( $\leq 3\text{GeV}$ ) ***⇒ Study properties of the medium via direct radiations and search for signal for Chiral symmetry***
- (4) Perform energy scan down to SPS energy ***⇒ Map the QCD phase diagram and search for the critical point.***

# Milestones

## RNC STAR Physics Milestones

	Measurements	Physics
FY 08	200 and 62.4 GeV Cu+Cu collisions $\phi$ spectra and $v_2$ analysis $J/\psi$ analysis in 200 Cu+Cu	
FY 09	1) Analysis high statistics FY07 data centrality dependence of $v_2$ for $\phi$ and $\Omega$ 2) Feasibility of full jet reconstruction in high-energy nuclear collisions at RHIC 3) PID at high $p_T$ ( $p_T \sim 15$ GeV/c)	1) Partonic velocity parameters 2) Color factor effect
FY 10	1) First RHIC energy scan starts 2) Analyze ToF data for di-electrons from $p+p$ collisions	Extract vector meson $\rho$ , $\omega$ , $\phi$ , $J/\psi$ mass distributions via di-electrons in $p+p$ collisions
FY 11	1) Analyze energy dependence data 2) Commissioning HFT patches	1) Search for critical point 2) Calibrate HFT and related simulations